STUDY OF FLASH FLOOD IN UTP ACADEMIC COMPLEX

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Study of Flash Flood in UTP Academic Complex

by

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Dissertation submitted in partial fulfillment of

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AZHARUL FITRI BIN ABDUL NIFA

CERTIFICATION OF APPROVAL

Study of Flash Flood in UTP Academic Complex

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A project dissertation submitted to the
Civil Engineering Programme
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in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

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(Husna bt. Takaijudin)

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ABSTRACT

It is important that every design of drainage system can meet the capacity of discharge in a catchment. This project objective is to evaluate the current drainage network and pond facilities in functioning to channel the stormwater directly to the main outlet located at UTP front gate and also to evaluate whether it meets the requirement of the new manual, Urban Stormwater Management for Malaysia. Through this project, the academic complex of UTP itself has been chosen as a case study. Throughout this project, design calculation has been carried out using the data obtained from the construction drawing. Measurement of current flow rate also has been done to be compared with. Based on calculation, the current drainage system mostly did not satisfy the MASMA requirement.

ACKNOWLEDGEMENT

Alhamdulillah, praise be to Allah. With his blessing, I have successfully completed my Final Year Project. Many people have contributed in the completion of my Final Year Project especially for allocation time, effort and suggestions for change.

Without help from others, this would not be achieved. Therefore, I would like to take this opportunity to thank those people who cooperated with me and gave me support throughout this one year period. Special gratitude towards my supportive and caring supervisor, Puan Husna binti Takaijudin, for without her guidance, I would not be able to finish my project. Special thanks also to my colleagues, Intan Mastura and Ainil Sharir, who had helped me a lot throughout the discussions made for this project purposes. Also not forgetting my parents who had always giving me the strength and support to make it through this Final Year Project, subsequently my bachelor degree.

Credit also should be given to all the staff of UTP Civil Engineering Department for their hands in helping me to complete my Final Year Project. The success of completing this project is achieved undoubtedly after experiencing the one year of hardship and difficulties. Nevertheless, with the help of others, I managed to complete the project and solve each difficulty successfully.

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List of Abbreviations

UTP – Universiti Teknologi PETRONAS

MASMA – Manual Saliran Mesra Alam Malaysia

DID – Department of Irrigation and Drainage

SUDS – Sustainable Urban Drainage System

BMP – Best Management Practice

LID – Low Impact Development

WSUD – Water Sensitive Urban Drainage

CHAPTER 1
INTRODUCTION

1.1 Background Study

Malaysia is not directly affected by serious natural disasters such as earthquakes, typhoons, hurricanes, tsunamis and volcanic eruption. This is because Malaysia is located just outside the volcanic, tornado, and severe drought belts. However, this does not make Malaysia free from natural disasters. Due to development, incidents such as landslides, sinkholes, and also flash floods have been recorded frequently in recent years. Based from Malaysia's Disaster Statistic from PreventionWeb, in 2007, the highest natural disaster recorded throughout the year was flood with 27 cases and had affected 137,533 people. Apart from development, another major factor that contributed to this incident is the climate of Malaysia itself. Malaysia, which experienced equatorial climate, received average annual rainfall of 2400 mm for Peninsular Malaysia, 3,800 mm for Sarawak and 2,600 mm for Sabah.

Heavy rainfall itself is one of the main causes of the river flooding. River capacity is exceeded with the resultant large concentration of runoff. However, in recent years, rapid development within river catchment has resulted in higher runoff and deteriorated river capacity; this has in turn resulted in an increase in the flood frequency and magnitude. With 60% of the Malaysian population now residing in urban areas, flash flooding in urban areas are perceived to be the most critical flood type (surpassing the monsoon flood) since the mid 1990's. This is reflected in the flood frequency and magnitude, social-economic disruption, public outcry, media coverage and the government's escalating allocation to mitigate them. One significant case regarding flash flooding in urban area was recorded back in 2006, when a large portion of Shah Alam was covered with water.

In regards to the flood problem, many studies had been conducted to identify the cause and solution (mitigation technique). Years back, engineering techniques are used to mitigate flood. This technique involved the usage of hydraulic structures such as reservoirs, dams, levees and monsoon drain to receive the stormwater. The government has adopted this technique in its first stormwater management manual back in 1975. However, as development increased, this method has been found not suitable to be practiced nowadays. Consequently, the government had introduced a new stormwater management manual in 2001 which emphasized in environmental approach in mitigating floods. This is further discussed in Chapter 2.

In conducting this study, several fieldworks has been conducted. After choosing the location of study, site survey is conducted to trace the network drainage of the location. The area of the location of study is determined using AutoCAD. Furthermore, peak flow of the inlet and outlet of the storage facilities are recorded for the assessment purposes. This is further discussed in Chapter 3.

1.2 Problem Statement

Since 1920, the country has experienced major floods in the years of 1926, 1963, 1965, 1967, 1969, 1971, 1973, 1979, 1983, 1988, 1993, 1998, 2005 and most recently in December 2006 and January 2007 which occurred in Johor. The January 1971 flood that hit Kuala Lumpur and many other states had resulted in a loss of more than RM 200 million then and the death of 61 persons. In fact, during the recent Johor 2006-07 flood due to a couple of "abnormally" heavy rainfall events which caused massive floods, the estimated total cost of these flood disasters is RM 1.5 billion, considered as the most costly flood events in Malaysian history. Recent urbanization amplifies the cost of damage in infrastructures, bridges, roads, agriculture and private commercial and residential properties. At the peak of that recent Johor flood, around 110,000 people were evacuated and sheltering in relief centers and the death toll was 18 persons.

Due to this, the Department of Irrigation (DID) have introduced the first urban drainage manual "Planning and ***Design*** Procedure No.1: ***Urban Drainage Design Standard*** for ***Peninsular Malaysia***, 1975." This manual has been used as a guideline for more than twenty-five years and since its publication, although there have been many new technological developments in urban area. Conventional drainage system, unfortunately has led to increase the occurrence of flash flood at the downstream of the catchments. Additionally, open drainage invites more polluted river and therefore has worsened the quality of life in urban community. Therefore conventional drainage is no longer an effective measure in solving flood.

In 2001, DID Malaysia have introduced a New Urban Drainage Manual known as Storm Water Management Manual for Malaysia (**Manual Saliran Mesra Alam Malaysia or MASMA**) to replace the old manual introduced in 1975. Effective from 1st January 2001, all new development in Malaysia must comply with the new guideline, which requires the application of Best Management Practices (BMP's) to control stormwater from the aspect of quantity and quality runoff to achieve zero development impact contribution. The main focus of Urban Storm Water Management Manual is to manage the stormwater instead of draining it away as fast as possible to a more environmentally approach known as control at source approach. This approach utilizes detention/retention, infiltration and purification process. This manual also considers the existing problem such as flash flood, river pollution, soil erosion, hill development and etc.

1.3 Scope of Study

This study will extensively use MASMA to assess the existing retention pond facilities for an existing living area. The proposed location for this study is at the academic complex of Universiti Teknologi PETRONAS, Tronoh. It is found that several locations are prone to flood after heavy rain. Therefore, by assessing the current storage facilities, it can determine whether it is adequate or not for current condition.

1.4 Objective of Study

The primary objective of the study is to evaluate the current drainage network and pond facilities in functioning to channel the stormwater directly to the main outlet located at UTP front gate. This will be carried to the second objective, which is to evaluate whether it meets the requirement of the new manual, Urban Stormwater Management for Malaysia.

CHAPTER 2
LITERATURE REVIEW

2.1 Overview of hydrologic cycle

The term rainfall is used to describe precipitations in the form of water drops of sizes larger than 0.5 mm. The maximum size of a raindrop is 6 mm. Any drop larger in size than this tends to break up into drops of smaller sizes during its fall from the clouds. Based on hydrologic cycle, water on land surface is retained when wind blow the clouds towards the land area and then precipitated onto the land mass as rain, snow, hail, and sleet.

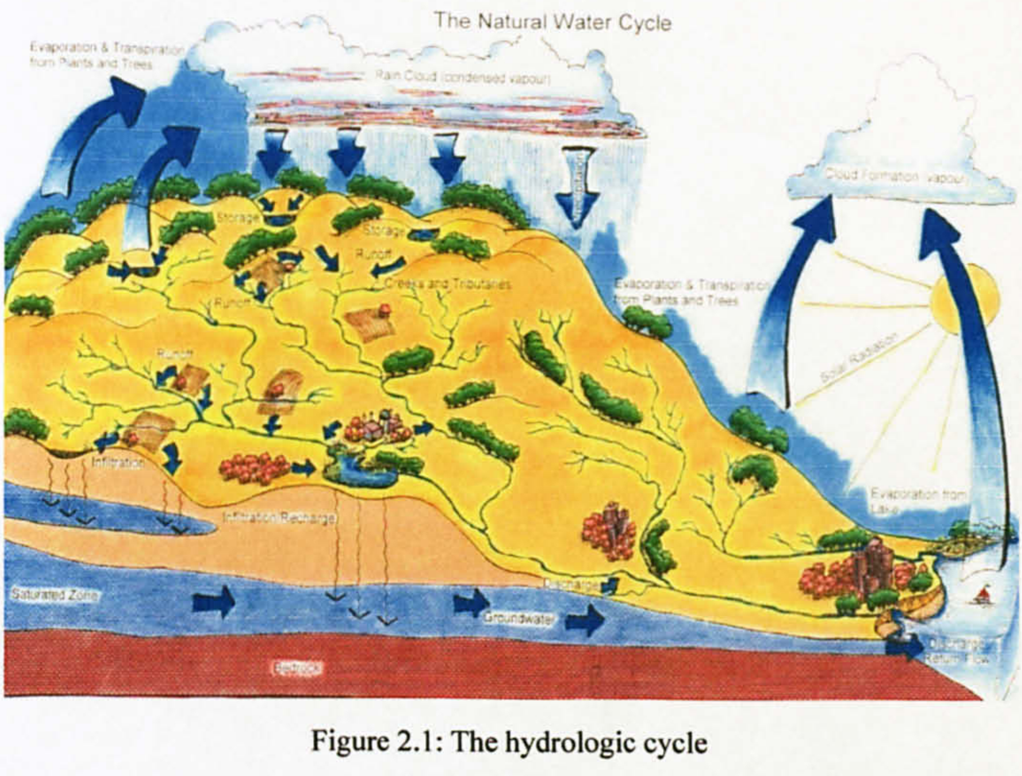

Figure 2.1: The hydrologic cycle

Hydrologic cycle is defined as a cycle that relates the various state of water on earth from liquid to gaseous to solid. Physical processes involved in the cycle include evaporation, precipitation, surface runoff, transpiration and infiltration. This cycle is best described as starting from the ocean where the water evaporated and formed the clouds. The clouds then got heavier due to accumulated water vapor, and then precipitated to the land in the form of rain, snow, drizzle, hail or sleet. This precipitate is then known as runoff. Runoff from higher location will then make its way back to the stream or infiltrate the groundwater. The stream then will lead back to the ocean thus completing the cycle.

2.2 Definition of flash flood and urban stormwater

S.N. Ghosh (2006) defines flash flood as a result due to heavy rains in hilly areas which cause local rivers and small streams to rise to dangerous level within a short period of time say 6 to 12 hours. He also stated that heavy and continuous rains in local areas can cause flash floods. He continued on to define urban flooding as a result of local heavy rains up to 100 mm or more in a day over the city and larger towns can cause damaging and disruptive flooding due to poor or choked drainage and rapid runoff. Flash floods have sharp peak, the rise and fall are almost equal and rapid. Urban stormwater runoff is water from precipitation and landscape surface flows which do not infiltrate into the soil. Under natural and undeveloped conditions, surface runoff can range from 10 to 30 percent of the total annual precipitation.

2.3 Stormwater management approach

2.3.1 Conventional approach

This technique involved the usage of hydraulic structures such as reservoirs, dams, levees and monsoon drain to receive the stormwater before it is released to the river. The government, through the Department of Irrigation and

Drainage has adopted this technique in its first stormwater management manual, "Planning and *Design* Procedure No.1: *Urban Drainage Design Standard* for *Peninsular Malaysia*, back in 1975. Rapid development has in turn increased the number of runoff thus making this approach not practical nowadays.

2.3.2 Environmental approach

This technique implements the concept of storage of stormwater rather than rapid disposal as such being practiced in the conventional approach. Examples of this approach currently in practice are Sustainable Urban Drainage System (SUDS) in United Kingdom, Best Management Practice (BMP) and Low Impact Development (LID) practiced in United States and also Water Sensitive Urban Design (WSUD) practiced in Australia. Examples of system to these approaches involve retention and/or detention pond, swales, water harvesting, porous pavement and wetland.

2.4 Stormwater management in Malaysia

In Malaysia, flash flood usually occurs during the rainy season. Lately, frequent number flash floods have been recorded especially in the urban area. As shown in Figure 2.1, the hydrologic cycle will maintain the volume of water on earth. However, as time passes by, the cycle gets 'disturbed' due to various reasons. As a result, frequent cases of flash floods have been reported yearly.

Chan (1997) had discussed the increasing flood risk in Malaysia. In his paper, he had stated several causes and solution for this problem based on his study. Deforestation and commercial logging have lessened the water retention area. Due to this, increased number of runoff will straight go to the stream. This will cause the stream water level to rise, thus flooding its bank. Apart from it, runoff also carries sediments with them. These sediments will then accumulate on the riverbed, slowly decreasing the river capacity.

For example, in Georgetown, the capacities of Sungai Pinang, Sungai Air Itam, Sungai Air Terjun and other rivers that drain the city have not increased since the colonial. In fact, the rivers' capacities have been significantly reduced because of siltation, rubbish dumping and constriction of channels due to squatting and other artificial developments on river banks (Chan, 1997).

As the runoff make its way to the urban areas, less soil area is found. Year by year, soil is being covered by artificial surfaces such as concrete and asphalt (road) pavements. As a result, the runoff would not be able to infiltrate the ground and remained on the land. This runoff will make its way to the storm drain before eventually reaching the river. Problem arises when these drains are clogged and some are no longer sufficient to cater the amount of runoff nowadays thus resulting in urban flash floods.

Previous practices to control flood involves the structural approach. This approach involves the construction of artificial structures such as dams, reservoirs, embankments, levees, retention ponds, diversion channels etc. to control floods (Chan, 1997). However, as time passes by, this method has not been very practical to use as it is becoming more expensive. The Department of Irrigation and Drainage (DID) has then introduced a New Urban Drainage Manual known as "Manual Saliran Mesra Alam Malaysia" in 2001 to serve as a guideline for flood preventing measure in non-structural ways. Non-structural measures highlighted include storage using retention and detention pond. Retention pond is a pond where runoff is collected and stored at full capacity. When excess water runoff occurs, it will then flow into the storm sewer system. Detention pond is a pond where runoff is collected and released to the storm sewer at the same time. However, the outflow of the pond is smaller than the inflow of the pond.

CHAPTER 3
METHODOLOGY

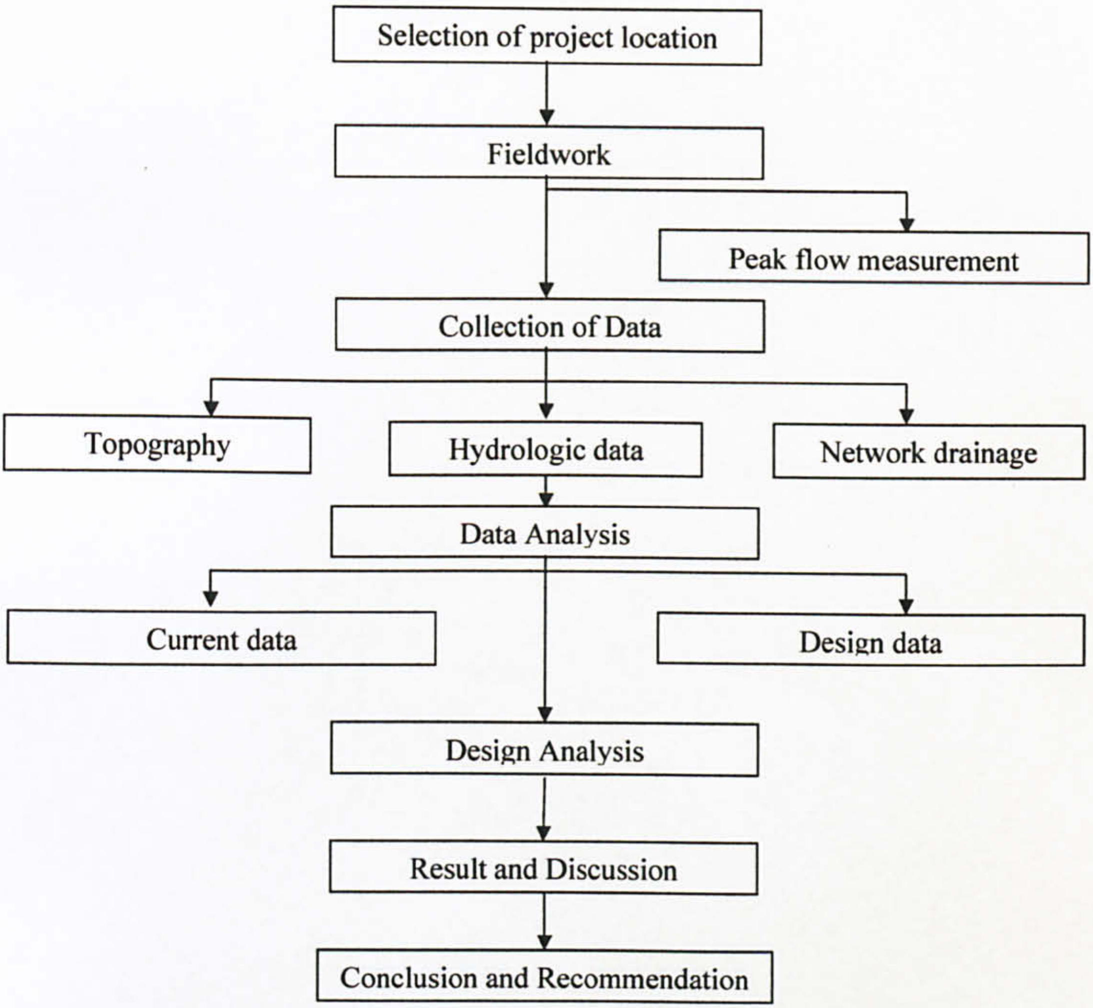

Figure 3.1: Summary of Methodology

The project location chosen for this study is the academic complex of Universiti Teknologi PETRONAS (UTP). The total area of UTP itself is 400 hectare while the academic complex encompassed approximately around 61 hectare. Through observation, it is found that UTP has implemented the MASMA concept with the existence of several retention ponds as its storage facilities. As the study is to assess the current network drainage and storage facilities, master plan of UTP – specifically the drainage layout – is referred.

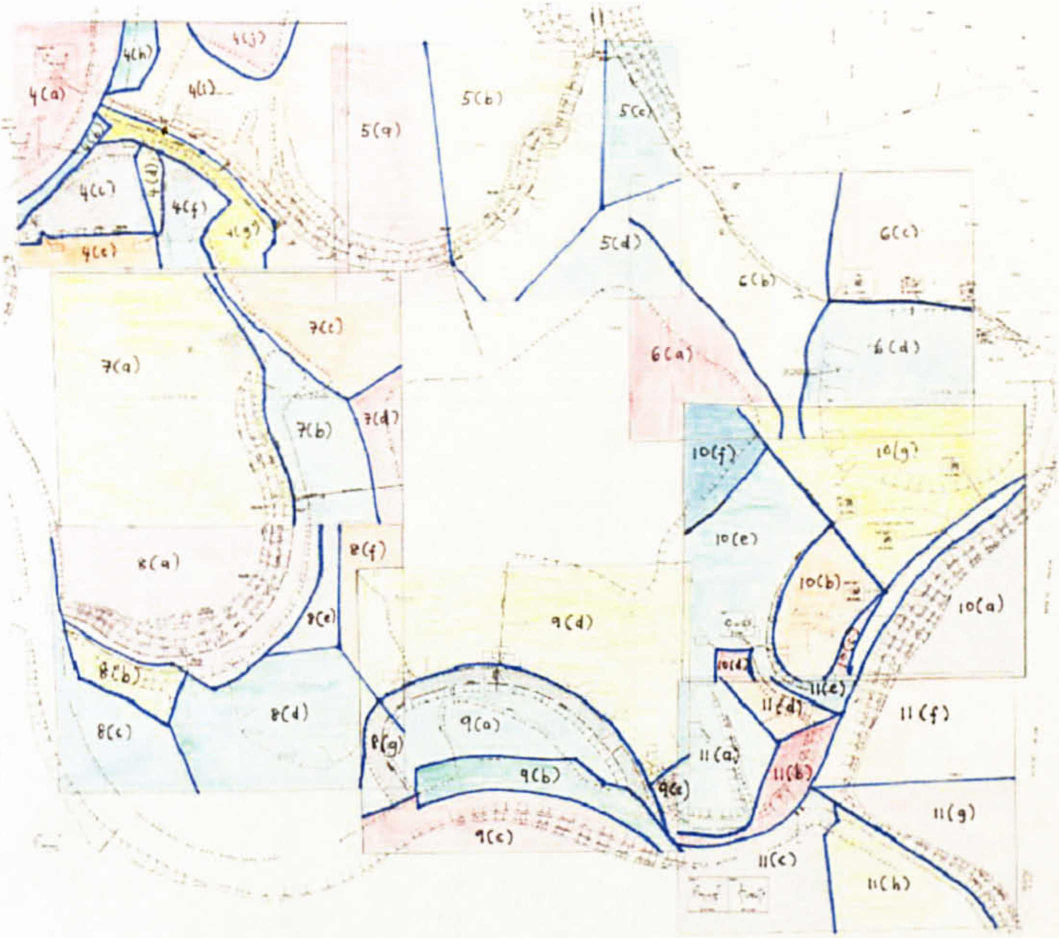

Figure 3.2: Location of Study – Academic Complex

Figure above shows the location of study. Different boxes denote the separate sheets for the construction drawing while different color represents the catchment area for each sheet. The catchments are name based on the sheet it is on. Areas of each catchment are calculated using AutoCAD 2007 and recorded in Appendix A.

3.1 Fieldwork

3.1.1 Peak flow measurement

Peak flow measurement is done by using the flow meter. The flow is measured directly after heavy rain to obtain the peak flow. The location where this is carried out is behind the Block 14, near the hill side. The purpose of taking this measurement is to obtain the current peak flow. By this, it can be compared to the design peak flow used when the storage facilities were built initially.

Figure 3.3: Measuring peak flow using hydrometer

3.2 Collection of Data

3.2.1 Topographic Data

Based on the UTP master plan (drainage layout), the topography of UTP terrain is hilly. Several existing hills has been maintained and terraced. Each of these terraced contours has been complimented with its hillside drain which subsequently flows down to the roadside drain.

3.2.1.1 Usage of AutoCAD 2007

The software, AutoCAD 2007 is used to extract the information from the construction drawing. Information concerned is; drain length, area of catchment, and overland length. Information obtained will then be recorded in tables for analysis part using Microsoft Excel 2007.

3.2.2 Hydrologic Data

Due to unavailability of equipment on site, rainfall data is obtained from the Department of Irrigation and Drainage (DID). The data is from Bota weather station where it shall be used to represent the rainfall data for the location of study. Weibull Plotting Position is used to plot

3.2.3 Network Drainage

From the plan, the network drainage is traced. The drainage capacity is also checked to clarify whether the design capacity can still hold current runoff. The nodes between sumps are drawn out to identify the flow or the stormwater.

3.3 Design Analysis

After obtaining the information from the AutoCAD drawing, analysis is carried out based on the MASMA. The volumes referred from MASMA are Volume 4: Design Fundamentals and Volume 5: Runoff Estimation. Calculation of flow time is carried out using the Excel spreadsheet by integrating the formulas as follows

3.3.1 Overland Flow Time and Drain Flow Time

Overland flow can occur on either grassed or paved surfaces. The major factors affecting time of concentration for overland flow are the maximum flow distance, surface slope, surface roughness, rainfall intensity, and infiltration rate.

Equation 3.1 below, known as Friend's formula, should be used to estimate overland sheet flow times:

$$t_0 = \frac{107n\, L^{\frac{1}{3}}}{S^{\frac{1}{2}}} \qquad \text{Equation 3.1}$$

where,

t_0 = overland sheet flow travel time (minutes)

L = overland sheet flow path length (m)

n = Manning's roughness value for the surface

S = slope of overland surface (%)

The time stormwater takes to flow along an open channel may be determined by dividing the length of the channel by the average velocity of the flow. The average velocity of the flow is calculated using the hydraulic characteristics of the open channel.

The Equation 3.2 (Manning's formula) is recommended for this purpose:

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \qquad \text{Equation 3.2}$$

from which,

$$t_d = \frac{nL}{60} R^{\frac{2}{3}} S^{\frac{1}{2}} \qquad \text{Equation 3.3}$$

where,

V = average velocity (m/s)

n = Manning's roughness coefficient

R = hydraulic radius (m)

S = friction slope (m/m)

L = length of channel (m)

t_d = travel time in the channel (minutes)

In obtaining this two value of times, determination of time of concentration (t_c) can be equated as shown in Equation 3.4 below:

$$t_c = t_0 + t_d \qquad \text{Equation 3.4}$$

Where the value of t_c will afterwards be used in determining the calculation of rainfall intensity, I.

3.3.2 Rational Method

Rational Method relates peak runoff to rainfall intensity through a proportionality factor. During a rainfall of uniform intensity and long duration, the runoff rate gradually increases from zero to a constant value (Subramanya, 2009). The peak value of the runoff is given by the Rational Formula;

$$Q_y = \frac{C\,{}^{y}_{t}I\,A}{360} \qquad \text{Equation 3.5}$$

where,

Q_y = y year ARI peak flow (m^3/s)

C = dimensionless runoff coefficient

${}^{y}I_t$ = y year ARI average rainfall intensity over time of concentration, t_c, (mm/hr)

A = drainage area (ha).

*ARI stands for Average Recurrence Interval.

3.3.3 Sample Calculation

For explanation purpose, the catchment of 4.A is taken to demonstrate this calculation. ARI used for this project purpose is 2 years. We can calculate t_c by using Equation 3.1, 3.3 and 3.4:

$$t_0 = \frac{107\,(0.03)\,(167.31)^{\frac{1}{3}}}{(0.4)^{\frac{1}{2}}} \qquad \text{Equation 3.6}$$

$$t_0 = 25.64\, minutes \qquad \text{Equation 3.7}$$

$$t_d = \frac{155.3}{64.58} = 2.404\, minutes \qquad \text{Equation 3.8}$$

From Equation 3.7 and Equation 3.8 above, the value of t_c is:

$$t_c = 25.64 + 2.404 = 28.04\, minutes \qquad \text{Equation 3.9}$$

Based on the MASMA, if t_c obtained is less than 30 minutes, correction factor must be used to obtain the rainfall intensity, *I*. Equation 3.10 below is the polynomial approximation of Intensity-Duration-Frequency (IDF) curves. The coefficient is chosen from Ipoh data from Appendix 13.A of MASMA Volume 4.

$$\mathrm{Ln}({}^R_t I) = a + b\ln(t) + c\,(\ln(t))^2 + d(\ln\,(t))^3 \qquad \text{Equation 3.10}$$

By using this equation, the value of I_{30} and I_{60} can be obtained. Here on, the values are converted back to precipitation, P_{30} and P_{60}. The precipitation values will then be used in Equation 3.11:

$$P_{d=}P_{30} - F_D(P_{60} - P_{30}) \qquad \text{Equation 3.11}$$

where F_D is the correction factor obtained from MASMA and P_d is the design rainfall depth. For this example, P_d obtained is 50.99mm. The value is then converted by dividing with value of t_c over 60:

$$I = \frac{P_d}{(\frac{t_c}{60})} = 109.11\, mm/hr \qquad \text{Equation 3.12}$$

After obtaining this value of *I*, then proceeded with the Rational Method formula (Equation 3.5). The value of runoff coefficient, *C*, is obtained from Design Chart 14.3 of MASMA Volume 5.

$$Q = \frac{CIA}{360} = 0.943 m^3/s \qquad \text{Equation 3.13}$$

The rest of the calculation is carried out using Microsoft Excel 2007 spreadsheet as per attached in Appendix B.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Fieldwork

Based on observation done, the actual flow rate is lesser than peak flow. So, due to this, the current drain can actually cater the discharge. However, in calculation it proved otherwise. During carrying out the fieldwork also, the author noticed that the location of fieldwork, behind block 14, contained lots of sediment with the depth of approximately 50cm along the channel. This could potentially cause overflow during peak discharge. During the storm event, the velocity of water will increase and it can exceed the capacity of drain due to this problem.

This study is also limited and focusing on the main drain located around the academic complex.

Figure 4.1: Sedimentations and Vegetations along Channel

Table 4.1: Results of fieldwork done

Date	Rain Duration (hours)	Water Depth (cm)	Average Velocity (m/s)	Flowrate, Q (m^3/s)
10/05/2010	0.5	12.7	0.09	0.12
29/05/2010	1	20	0.13	0.17
31/05/2010	1.5	40	0.64	0.92

Table above shows the result of the fieldwork done. For the first two fieldworks, the velocity of water in the drain is so low, conventional method had to be used. A floating object was put on the water and the time traveled between two points was recorded via a video camera.

The first two fieldworks was carried out using the conventional method since the flowmeter was not able to measure the velocity. The third one, which consequence to the flood, was measure using the flowmeter.

Results showed that the drainage should be able to cater the flowrate when comparing with the design calculation. However, several other factors should be considered such as the vegetations and sedimentations in the channel that might contribute to the overflow of the drain.

4.2 Design Calculation

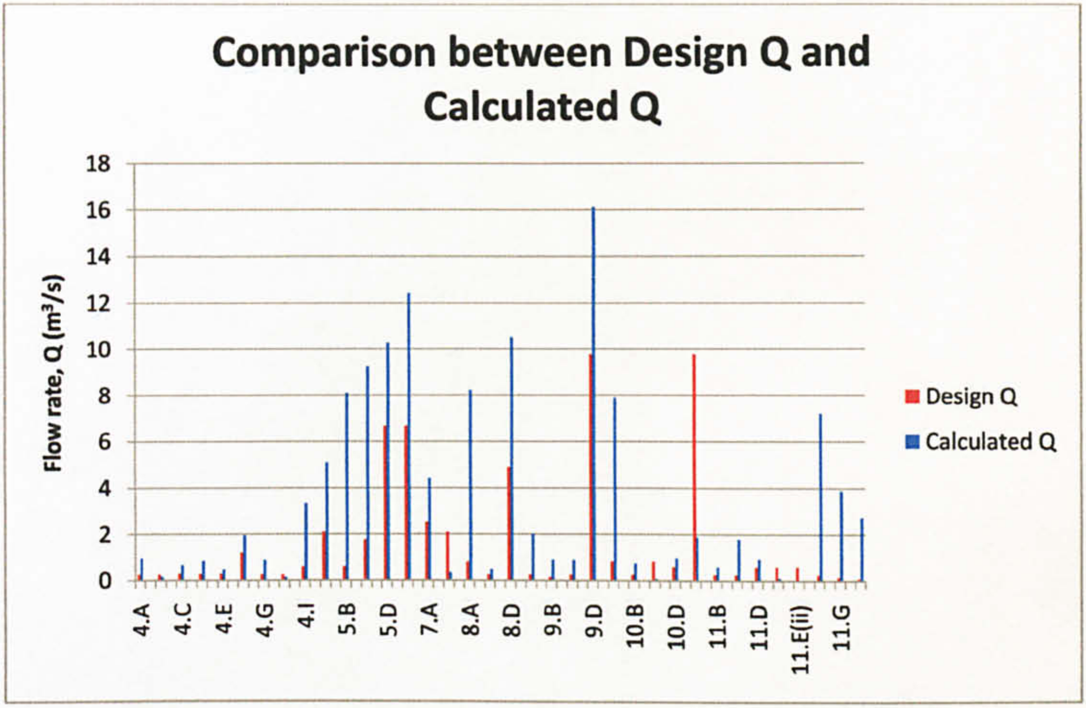

Figure 4.2: Comparison between Design Q and Calculated Q from Design Calculation

Based on the calculation that had been done, it can be seen that most of the calculated drain capacity (Q) had exceeded design capacity of the drain itself. This happen because during the construction, the contractor may not actually follow the MASMA concept. Different method used may lead to different result thus not suit the MASMA.

4.3 Proposed Change to Current Design

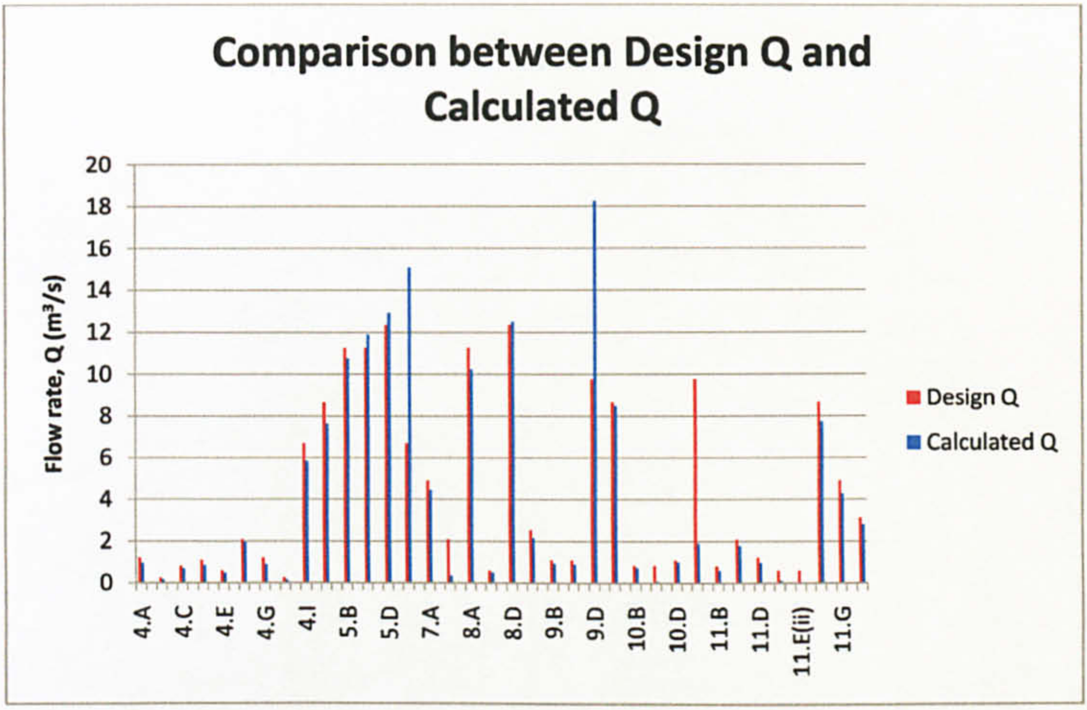

Figure 4.3: Comparison between Design Q and Calculated Q from Proposed Change

The proposed change to current design is actually by replacing the drains with another one that can caters bigger capacity. The replacement drain is from the design of available drains in the location of study itself. As shown in Figure 4.2 above, after adjustment to bigger capacity drain, most Design Q exceeded the Calculated Q. This means that with the proposed change, the drainage can cater the runoff from respective area. It can also be seen that drainage from catchment 6.B and 9.D still not sufficient in catering the runoff. Solution can be proposed is that by having twin channel to overcome the problem or having much bigger capacity of drain (which is not currently in use on site).

4.4 Rainfall Analysis

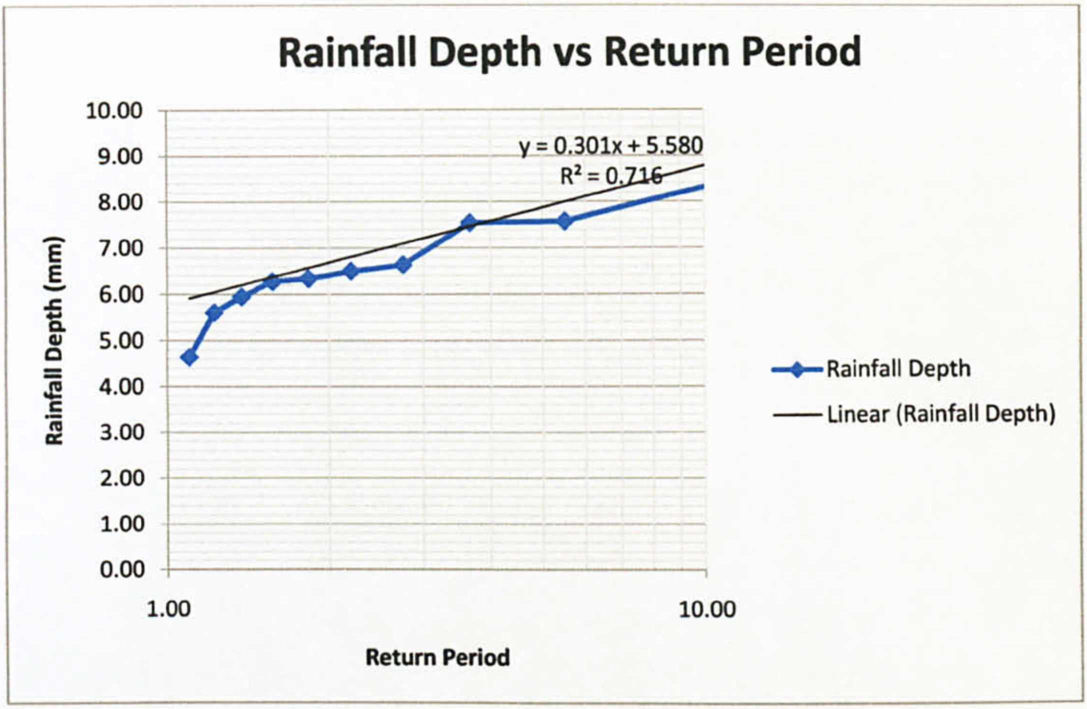

Figure 4.3: Rainfall Depth vs Return Period

Figure above shows the rainfall depth vs return period based on Weibull plotting position. By interpolation, it is found that when return period, T, is equal to 2, the corresponding rainfall intensity is 0.008947mm/hr which is very small. The data might not be accurate enough as this was obtained for a mere representative purpose of the study area. Therefore, it is recommended that more data from other weather station is obtained to get more accurate result.

CHAPTER 5
ECONOMIC BENEFITS

This study mainly focuses on the analysis part. Since the location is located inside of UTP itself, certain costs such as transportation cost had actually been minimized. Equipments used such as the flowmeter, measuring tape and safety boots are all obtained from the laboratory. Rainfall data is obtained from DID which involved no cost since it is used for academic purposes while the construction drawings are all obtained in soft copy, thus not involving cost.

However, during the observation done in this study, a flood had occurred. This has led to losses in terms of the affected vehicles parked near to the overflowed drain. As for example, Dr. Ibrahim Kamarudin's car had been a casualty in the incident with the repair cost had been estimated around RM2000. Other vehicles that had been affected include Dr. Nasiman's car and also another student. These losses had further strengthened the findings of the study which is to upgrade the identified drain with bigger dimension ones to cater for the peak discharge. Estimation of several drain size construction are listed in table below.

Table 5.1: Cost Estimation for Drain Construction according to size

Drain Type	Width (m)	Price (RM)
Twin Drain	2.5	5050 per linear meter
Twin Drain	3.0	6080 to 6100 per linear meter
Single Drain	4.0	5180 per linear meter
Single Drain	2.0	2500 per linear meter
Twin RC pipe culvert	1.5	25000 each (lump sum)

This estimation is acquired from an ongoing flood mitigation project entitled "*Construction and completion of flood mitigation at Sg. Maong Paroh, Kuching, Sarawak.*" It was issued by the DID itself.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

From the results obtained, it is shown that certain constructed drainage is not able to cater for the peak discharge. Observation done also shown that the selected area is prone to yet another flooding incident. The drainage provided has overflowed yet again. All in all, in meeting the objectives of the study, the current drainage system at UTP is not fully able to cater peak discharge and also not up to the MASMA requirement.

Recommendations that can be made in improving the drainage system of UTP is to upgrade the drainage in areas that had been identified in the study as per proposed in the calculation table in Appendix C. Certain drainage replacement has not been able to be identified in the study because of the limited dimensions of on-site used drain. For these drains, bigger dimension rather than available ones are recommended to be used. It has also been observed that certain drainages are prone to silting, sedimentation and also vegetation along the drainage span. Therefore, it is important to conduct regular de-silting and remove the vegetation as to avoid the water level to rise above its limit capacity. The slope of hillside that is located near to the drainage also needs to be well maintained. If not, during heavy rain, it will cause the runoff to take the sediments into the drain.

For the purpose of future study regarding this topic, the weather station in UTP should be frequently maintained and use to record the real rainfall data itself. This is to further increase the accuracy of the real rainfall data obtained, which in this study is only from Bota weather station. The average of the two weather station data can be used to improve the result. Another part that can be considered for future study is the integration of conventional and MASMA method in terms of stormwater quality such as removal efficiency of pollutant at source. Parameters such as Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) can be used to determine the quality of the stormwater.

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APPENDIX A –

CATCHMENT INFORMATION

FROM AUTOCAD

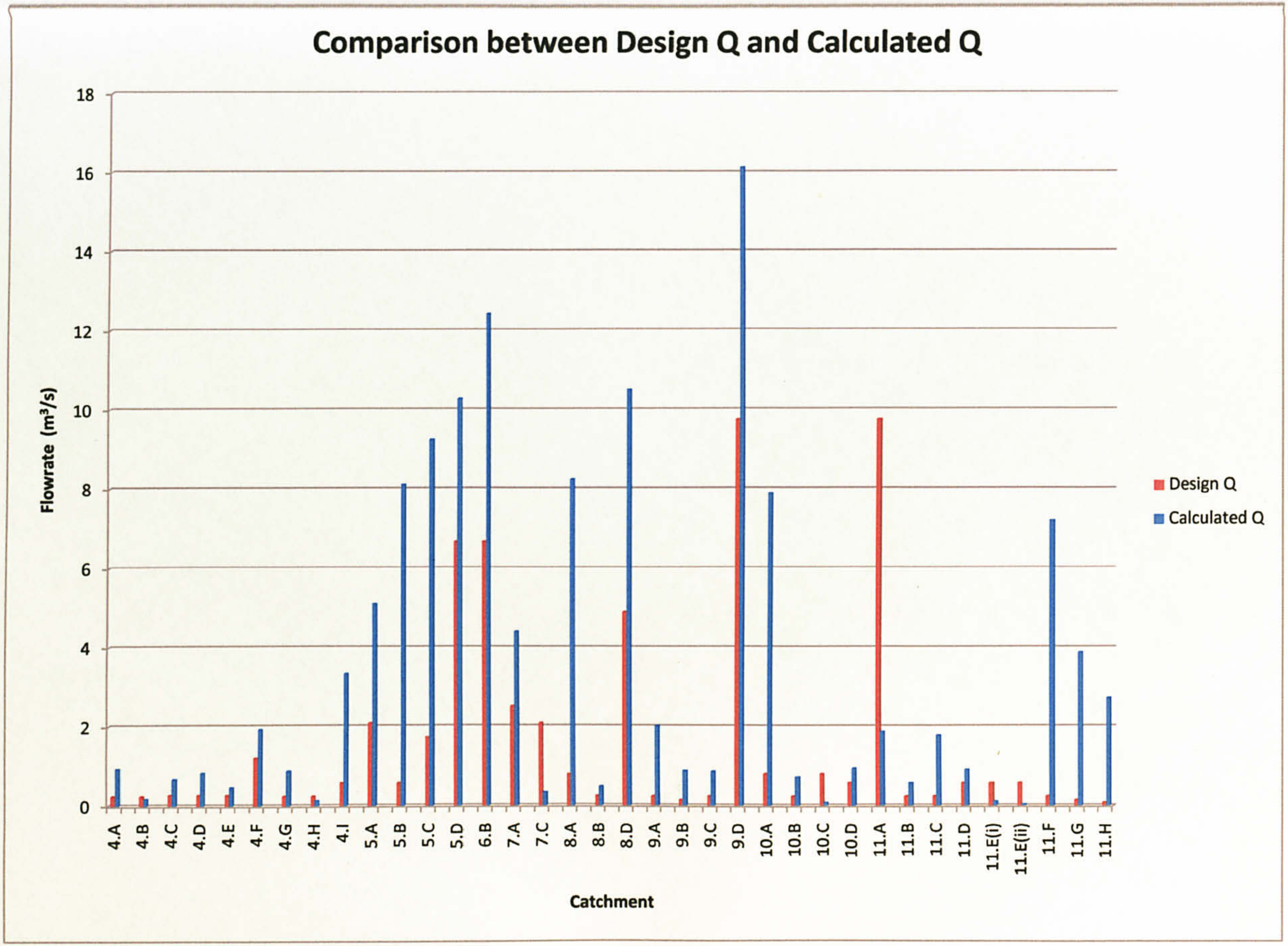
Catchment		Area (m^2)	Area (ha)	Nodes	manning	overland length	Overland slope (%)
4	a	42061.16	4.2061161		0.25	167.308	0.4
	b	5698.181	0.5698181	C	0.25	34.178	0.3
	c	30679.594	3.0679594	A	0.25	177.229	0.4
	d	4592.135	0.4592135	A -> A1 -> A2	0.25	37.746	0.4
	e	23146.128	2.3146128	A2 -> A3	0.25	265.462	0.4
	f	20437.547	2.0437547	A1 -> A2 -> A3 -> C5	0.25	54.608	0.4
	g	27930.252	2.7930252	C -> C1 -> C2 -> C3 -> C31	0.25	111.888	0.4
				C -> C1 -> C2 -> C3 -> C4			
	h	3802.966	0.3802966	B	0.25	28.56	0.4
	i	133867.914	13.386792	B -> B1 -> B2 -> B3 -> B4 -> B5 -> B6 -> B7 -> B8	0.25	343.737	0.4
	j	4406.048	0.4406048		0.25	-	0.4
5	a	97859.674	9.7859675	B9	0.25	449.31	0.4
	b	162706.802	16.27068	B9 -> D -> D1 -> D2	0.25	313.024	0.4
				D -> E	0.25		
	c	53743.272	5.3743273	D3	0.25	217.543	0.4
	d	37157.776	3.7157776		0.25	103.068	-
6	a	107363.609	10.736361		0.25	-	-
	b	103115.677	10.311568	D4 -> D5	0.25	165.657	0.3
	c	70717.373	7.0717374	D5 - > D6	0.25	-	0.3
	d	84275.714	8.4275715	D5 - > D6	0.25	?	0.4
7	a	47983.908	4.7983909	C6	0.25	391.994	4
	b	12291.804	1.2291804	C6 -> C61	0.25	x	?
	c	14152.541	1.4152541		0.25	?	0.3
	d	5574.157	0.5574157		0.25	-	-
8	a	125949.999	12.595	FI -> C8 <-C7	0.25	259.238	3
	b	15756.57	1.575657	F11	0.25	54.211	0.4
	c	46479.779	4.647978		0.25	-	0.4
	d	94035.874	9.4035875	C81	0.25	141.031	0.5
	e	16246.756	1.6246756	C7	0.25	?	0.3
	f	37349.073	3.7349073		0.25	?	0.3
	g	15454.462	1.5454462		0.25	?	0.3
9	a	84605.447	8.4605448	J1 -> J2 <- J3	0.25	126.686	0.3
	b	35516.284	3.5516284	H -> H1	0.25	63.588	0.3
	c	29986.515	2.9986515		0.25	66.089	0.4
	d	192573.089	19.257309	C82 -> J5 -> C83 -> G5	0.25	249.247	0.3
	e	8477.587	0.8477587		0.25	?	0.3
10	a	18024.561	1.8024561	I3 -> I4 -> H24	0.25	316.028	3
	b	9479.921	0.9479921	H4 -> H5 , G1 ->G	0.25		0.3
				G1 -> G	0.25		
	c	1495.608	0.1495608		0.25	46.051	0.3
	d	1128.173	0.1128173	G3	0.25	88.943	0.3
	e	17461.959	1.7461959	G3 -> G2 -> G1	0.25	221.134	0.3
				H3 -> H4 -> H5			
	f	4698.395	0.4698395	K	0.25	-	-
	g	23657.547	2.3657547	K -> H5 -> G -> H22 -> H23 -> H24	0.25	?	1
11	a	44313.942	4.4313943	G4	0.25	?	1
	b	25443.944	2.5443944	H2	0.25	91.15	0.3
	c	55597.371	5.5597372	I	0.25	195.071	1
	d	14338.736	1.4338736	H2	0.25	93.901	0.3
	e	8508.797	0.8508797	H21	0.25	47.423	0.1
	f	84671.676	8.4671677	I1 -> I2	0.25	381.409	3
	g	70109.59	7.0109591	I1	0.25	173.788	3
	h	48387.28	4.8387281		0.25	179.851	0.3

APPENDIX B –

DESIGN CALCULATION

APPENDIX B - Design Calculation

Area	Catch. Area (ha)	Length of Overland (m)	n	slope %	to (min)	Length of Drain (m)	v (m/min)	td	tc (min)	Fd	tc = 30 min (2-yr ARI)							tc = 60 min (2-yr ARI)							P_t	${}^{2}I_t$ (mm/hr)	C	Q (m^3/s)	Q link (m^3/s)	Drain Size (P.C Block + BS)	Design Slope	Drain Capacity (m^3/s)	Drain Velocity (m/s)
											a 5.2244 a	b 0.3653 b ln(30)	c -0.197 c $ln(30)^2$	d 0.01 d $ln(30)^3$	ln(t)	${}^{2}I_{30}$ (mm/hr)	P_{30} (mm)	a 5.2244	b 0.3653 b ln(60)	c -0.197 c $ln(60)^2$	d 0.01 d $ln(60)^3$	ln(t)	${}^{2}I_{60}$ (mm/hr)	P_{60} (mm)									
4.A	4.21	167.308	0.03	0.40	25.6366	155.25	64.5759	2.40415	28.0406	0.094	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	50.994	108.11405	0.739	0.943	0.943	600mm BD	1:200	0.2583037	1.076266
4.B	0.57	34.178	0.03	0.30	17.4343	108.313	64.5759	1.6773	19.1116	0.536	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	45.032	141.37476	0.79	0.177	0.177	600mm BD	1:200	0.2583037	1.076266
4.C	3.07	177.229	0.03	0.40	26.1335	131.099	71.2669	1.83955	27.9731	0.141	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	50.36	108.01776	0.73	0.672	0.672	600mm x 400mm U-Drain	1:300	0.2850678	1.187782
4.D	0.46	37.746	0.03	0.40	15.6067	88.991	71.2669	1.2487	16.8554	0.734	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	42.361	150.79167	0.81	0.156	0.829	600mm x 400mm U-Drain	1:300	0.2850678	1.187782
4.E	2.31	265.462	0.03	0.40	29.9011	104.357	71.2669	1.46431	31.3654	-	5.2244	1.3276	-2.3390	0.4091	4.6222	101.72	-	-	-	-	-	-	-	-	-	101.72	0.722	0.471	0.471	600mm x 400mm U-Drain	1:300	0.2850678	1.187782
4.F	2.04	54.606	0.03	0.40	17.6511	96.305	90.7758	1.08294	18.734	0.602	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	44.141	141.37264	0.798	0.639	1.939	600mmBD / 800mm x 700mm	1:200	1.2103434	1.512929
4.G	2.79	111.888	0.03	0.40	22.4189	138.085	64.5759	2.13803	24.5569	0.282	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	48.458	118.39722	0.758	0.696	0.872	600mm BD	1:200	0.2583037	1.076266
4.H	0.38	28.56	0.03	0.40	14.2213	66.9	64.5759	1.03599	15.2573	0.8	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	41.471	163.08483	0.82	0.141	0.141	600mm BD	1:200	0.2583037	1.076266
4.I	13.39	343.737	0.03	0.40	32.5908	250.665	73.8195	3.39565	35.9865	-	5.2244	1.6574	-2.5293	0.4600	4.8126	123.05	-	-	-	-	-	-	-	-	-	123.05	0.7	3.204	3.348	600mmBD / 800mm x 300mm	1:200	0.5905556	1.230324
5.A	9.79	449.3	0.03	0.40	35.6341	111.515	116.869	0.95418	36.5882	-	5.2244	1.3679	-2.5527	0.4665	4.5251	92.30	-	-	-	-	-	-	-	-	-	92.30	0.702	1.762	6.107	1200mm x 900mm U-Drain	1:300	2.1036502	1.947824
5.B	16.27	313.02	0.03	0.40	31.59	251.80	73.82	3.41	35.00	-	5.2244	1.3699	-2.4902	0.4494	4.5535	94.96	-	-	-	-	-	-	-	-	-	94.96	0.7	3.004	8.111	600mmBD / 800mm x 300mm	1:200	0.5905556	1.2303
5.C	5.37	217.54	0.03	0.40	27.9813	131.503	83.3465	1.57779	29.5591	0.047	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	51.628	104.79571	0.73	1.141	9.252	1200mm x 1050mm U-Drain	1:638	1.7502766	1.389106
5.D	3.72	103.07	0.03	0.40	21.8136	53.414	178.18	0.29978	22.1134	0.376	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	47.19	128.03974	0.78	1.032	10.284	1500mm x 1500mm U-Drain	1:200	6.6817404	2.969662
6.B	10.31	165.657	0.03	0.30	29.5048	149.813	178.18	0.8408	30.3456	-	5.2244	1.314694	-2.2943	0.3974	4.6424	103.80	-	-	-	-	-	-	-	-	-	103.80	0.725	2.156	12.440	1500mm x 1500mm U-Drain	1:200	6.6817404	2.969662
7.A	6.02	391.994	0.03	4.00	10.7675	262.45	113.092	2.32068	13.0881	0.992	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	38.881	178.24069	0.83	2.474	4.413	600mmBD / 1100mm x 1000mm	1:200	2.5257159	1.884863
7.C	1.42	105.456	0.03	0.30	25.3812	111.515	116.869	0.95418	26.3354	0.188	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	49.726	113.29035	0.75	0.335	0.335	1200mm x 900mm U-Drain	1:300	2.1036502	1.947824
8.A	14.22	259.238	0.03	3.0	10.8323	300.09	79.8496	3.75819	14.5905	0.896	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	40.176	166.21233	0.81	5.296	8.247	600mmBD / 600mm x 600mm	1:200	0.7984955	1.330826
8.B	1.58	54.211	0.03	0.4	17.6082	104.573	64.5759	1.61938	19.2276	0.536	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	45.032	140.52184	0.79	0.487	0.487	600mm BD	1:200	0.2583037	1.076266
8.D	9.4	141.031	0.03	0.5	21.6606	456.712	139.373	3.27689	24.9375	0.282	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	48.458	116.59057	0.745	2.268	10.816	600mmBD / 1700mm x 1100mm	1:200	4.9012999	2.322891
9.A	10.01	126.686	0.03	0.3	26.9815	286.361	64.5759	4.43448	31.4159	-	5.2244	1.328251	-2.3411	0.4097	4.6212	101.61	-	-	-	-	-	-	-	-	-	101.61	0.715	2.020	2.020	600mm BD	1:200	0.2583037	1.076266
9.B	3.55	63.586	0.03	0.3	21.4428	158.893	57.1851	2.77857	24.2213	0.282	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	48.458	120.0376	0.75	0.888	0.888	500mmBD	1:200	0.1588476	0.953086
9.C	3	66.089	0.03	0.4	18.8103	137.684	64.5759	2.13213	20.9424	0.47	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	45.922	131.56607	0.79	0.866	0.866	600mm BD	1:200	0.2583037	1.076266
9.D	19.26	249.247	0.03	0.3	33.809	286.36	197.243	1.45181	35.2608	-	5.2244	1.372736	-2.5006	0.4522	4.5488	94.52	-	-	-	-	-	-	-	-	-	94.52	0.71	3.590	16.126	1800mm x 1650mm U-Drain	1:200	9.7635489	3.28739
10.A	1.8	316.028	0.03	3.0	11.5717	240.955	81.2087	2.96711	14.5388	0.896	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	40.176	165.7999	0.812	0.673	7.886	600mmBD / 900mm x 400mm	1:200	0.8120674	1.353479
10.B	2.7	102.229	0.03	0.3	25.1197	143.429	64.5759	2.22109	27.3408	0.141	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	50.36	110.51593	0.74	0.613	0.734	600mm BD	1:200	0.2583037	1.076266
10.C	0.15	46.051	0.03	0.3	19.2561	168.953	81.2087	2.08048	21.3366	0.329	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	47.824	134.48405	0.772	0.043	0.087	600mmBD / 900mm x 400mm	1:200	0.8120674	1.353479
10.D	0.11	88.943	0.03	0.3	23.9806	31.466	73.8195	0.42651	24.4071	0.282	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	48.458	119.12403	0.76	0.026	0.968	600mmBD / 800mm x 300mm	1:200	0.5905556	1.230324
11.A	5.28	141.308	0.03	1.0	15.3263	114.631	197.243	0.58117	15.9075	0.8	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	41.471	156.41665	0.82	1.881	1.881	1800mm x 1650mm U-Drain	1:200	9.7635489	3.28739
11.B	2.54	91.15	0.03	0.3	24.1773	161.345	64.5759	2.34367	26.521	0.188	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	49.726	112.49769	0.74	0.587	0.587	600mm BD	1:200	0.2583037	1.076266
11.C	5.56	195.071	0.03	1.0	17.0653	74.67	64.5759	1.15631	18.2216	0.602	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	44.141	145.34834	0.8	1.796	1.796	600mm BD	1:200	0.2583037	1.076266
11.D	1.43	93.901	0.03	0.3	24.4181	87.738	73.8195	1.18855	25.6067	0.235	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	49.092	115.02897	0.75	0.343	0.930	600mmBD / 600mm x 400mm	1:200	0.5905556	1.230324
11.E(i)	0.63	47.423	0.03	0.1	33.6806	64.614	73.8195	0.8753	34.5559	-	5.2244	1.364955	-2.4723	0.4446	4.5616	95.74	-	-	-	-	-	-	-	-	-	95.74	0.72	0.121	0.121	600mmBD / 600mm x 400mm	1:200	0.5905556	1.230324
11.E(ii)	0.22	44.374	0.03	0.1	32.9427	14.43	81.2087	0.17769	33.1204	-	5.2244	1.348608	-2.4135	0.4288	4.5884	98.33	-	-	-	-	-	-	-	-	-	98.33	0.723	0.043	0.043	600mmBD / 900mm x 400mm	1:200	0.5905556	1.230324
11.F	8.47	381.409	0.03	3.0	12.3202	109.657	64.5759	1.69811	14.0184	0.896	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	40.176	171.95558	0.825	3.338	7.226	600mm BD	1:200	0.2583037	1.076266
11.G	7.01	173.788	0.03	3.0	9.48045	163.109	57.1851	2.8523	12.3328	1.088	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.2618	5.2244	1.5776	-3.3024	0.6884	4.1859	65.75	65.75	37.586	182.85792	0.83	2.955	3.887	500mmBD	1:200	0.1588476	0.953086
11.H	4.84	179.851	0.03	0.3	30.3245	156.125	49.2807	3.16808	33.4926	-	5.2244	1.362913	-2.4289	0.4329	4.5813	97.65	-	-	-	-	-	-	-	-	-	97.65	0.71	0.932	2.728	400mmBD	1:200	0.0876103	0.821344

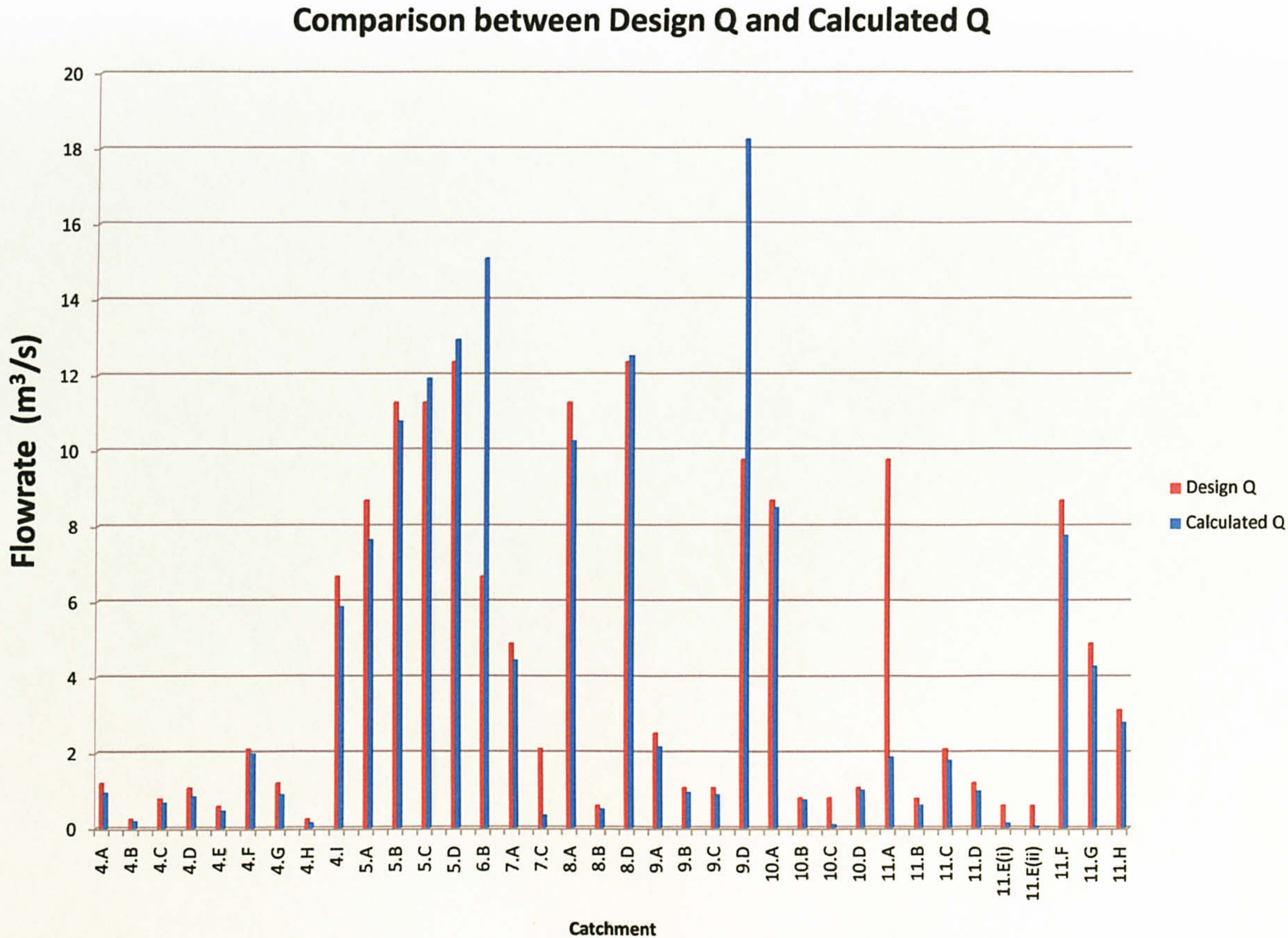

Comparison between Design Q and Calculated Q
Flowrate (m³/s)
0
2
4
6
8
10
12
14
16
18
Catchment
4.A
4.B
4.C
4.D
4.E
4.F
4.G
4.H
4.I
5.A
5.B
5.C
5.D
6.B
7.A
7.C
8.A
8.B
8.D
9.A
9.B
9.C
9.D
10.A
10.B
10.C
10.D
11.A
11.B
11.C
11.D
11.E(i)
11.E(ii)
11.F
11.G
11.H
Design Q
Calculated Q

APPENDIX C –

PROPOSED CHANGE

APPENDIX C - Proposed Change

Area	Catch. Area (ha)	n	slope %	to (min)	Length of Drain (m)	v (m/min)	td	tc (min)	Fd	tc = 30 min (2-yr ARI) a 5.2244 / a	b 0.3853 / b ln(30)	c -0.197 / c ln(30)^2	d 0.01 / d ln(30)^3	ln(I)	$^{10}I_{30}$ (mm/hr)	P_{30} (mm)	tc = 60 min (2-yr ARI) a 5.2244	b 0.3853 / b ln(60)	c -0.197 / c ln(60)^2	d 0.01 / d ln(60)^3	ln(I)	$^{10}I_{60}$ (mm/hr)	P_{60} (mm)	P_t	$^{10}I_t$ (mm/hr)	C	Q (m^3/s)	Q link (m^3/s)	Drain Size (P.C Block + BS)	Design Slope	Drain Capacity (m^3/s)	Drain Velocity (m/s)
4.A	4.21	0.03	0.40	25.6364967	155.25	90.775754	1.7103	27.347	0.141	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	50.36	110.49	0.722	0.933	0.933	600mmBD / 800mm x 700mm	0.005	1.210343393	1.5129292
4.B	0.57	0.03	0.30	17.4343085	108.313	64.575935	1.6773	19.112	0.536	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	45.032	141.37	0.79	0.177	0.177	600mm BD	1:200	0.258303739	1.0762656
4.C	3.07	0.03	0.40	26.1335297	131.099	79.849555	1.6418	27.775	0.141	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	50.36	106.79	0.73	0.677	0.677	600mmBD / 600mm x 600mm	0.005	0.798495549	1.3306259
4.D	0.46	0.03	0.40	15.6066655	88.991	76.568553	1.1622	16.769	0.734	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	42.361	151.57	0.828	0.169	0.838	600mmBD / 1200mm x 500mm	0.00333	1.071959735	1.2761425
4.E	2.31	0.03	0.40	29.9011067	104.357	73.819452	1.4137	31.315	-	5.2244	1.3270	-2.3368	0.4085	4.6232	101.82	-	-	-	-	-	-	-	-	-	101.82	0.722	0.472	0.472	600mmBD / 600mm x 400mm	0.005	0.590555617	1.2303242
4.F	2.04	0.03	0.40	17.651105	98.305	116.86946	0.8412	18.492	0.602	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	44.141	143.22	0.82	0.666	1.876	1200mm x 900mm U-Drain	0.00333	2.10365025	1.9478243
4.G	2.79	0.03	0.40	22.4189007	136.065	90.775754	1.5209	23.94	0.329	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	47.824	119.86	0.762	0.708	0.885	600mmBD / 800mm x 700mm	0.005	1.210343393	1.5129292
4.H	0.38	0.03	0.40	14.2212971	66.9	64.575935	1.036	15.257	0.8	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	41.471	163.06	0.82	0.141	0.141	600mm BD	1:200	0.258303739	1.0762656
4.I	13.39	0.03	0.40	32.5908162	250.665	178.17974	1.4068	33.998	-	5.2244	1.9969	-2.4496	0.4385	5.2102	183.13	-	-	-	-	-	-	-	-	-	183.13	0.84	6.721	6.863	1500mm x 1500mm U-Drain	0.005	6.681740386	2.9696624
5.A	9.79	0.03	0.40	36.634058	111.515	192.73474	0.5786	36.213	-	5.2244	1.3830	-2.5381	0.4625	4.5317	92.92	-	-	-	-	-	-	-	-	-	92.92	0.702	1.774	7.637	1800mm x 1500mm U-Drain	0.005	8.673063481	3.2122457
5.B	16.27	0.03	0.40	31.59	251.80	197.24	1.28	32.87	-	5.2244	1.3456	-2.4028	0.4260	4.5932	98.81	-	-	-	-	-	-	-	-	-	98.81	0.7	3.128	10.762	1800mm x 1650mm U-Drain	0.00667	11.27397523	3.7960
5.C	5.37	0.03	0.40	27.9813188	131.503	83.346504	1.5778	29.559	0.047	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	51.628	104.8	0.73	1.141	11.904	1800mm x 1650mm U-Drain	0.00667	11.27397523	3.7959513
5.D	3.72	0.03	0.40	21.8136206	53.414	178.17974	0.2998	22.113	0.376	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	47.19	128.04	0.78	1.032	12.936	1800mm x 1650mm U-Drain	0.008	12.35002109	4.1582563
6.B	10.31	0.03	0.30	29.5047841	149.813	178.17974	0.8408	30.346	-	5.2244	1.3149	-2.2943	0.3974	4.6424	103.80	-	-	-	-	-	-	-	-	-	103.80	0.725	2.166	16.091	1500mm x 1500mm U-Drain	1:200	6.681740386	2.9696624
7.A	6.02	0.03	4.00	10.7674521	262.45	139.37346	1.8831	12.651	1.068	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	37.586	178.26	0.83	2.474	4.449	600mmBD / 1700mm x 1100mm	0.005	4.90129992	2.322891
7.C	1.42	0.03	0.30	25.3812482	111.515	116.86946	0.9542	26.335	0.188	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	49.726	113.29	0.75	0.336	0.335	1200mm x 900mm U-Drain	1:300	2.10365025	1.9478243
8.A	14.22	0.03	3.0	10.8323346	300.09	79.849555	3.7582	14.591	0.898	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	40.176	165.21	0.81	6.296	10.254	1800mm x 1650mm U-Drain	0.00667	11.27397523	3.7959513
8.B	1.58	0.03	0.4	17.6082265	104.573	73.819452	1.4166	19.025	0.536	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	45.032	142.02	0.8	0.499	0.499	600mmBD / 600mm x 400mm	0.005	0.590555617	1.2303242
8.D	9.4	0.03	0.5	21.6605592	456.712	139.37346	3.2769	24.937	0.282	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	48.458	116.59	0.745	2.268	12.602	1800mm x 1650mm U-Drain	0.008	12.35002109	4.1582563
9.A	10.01	0.03	0.3	26.9814562	286.361	113.09176	2.5321	29.514	0.047	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	51.628	104.96	0.74	2.160	2.160	600mmBD / 1100mm x 1000mm	0.005	2.525715875	1.8848626
9.B	3.55	0.03	0.3	21.4427706	158.893	76.568553	2.0752	23.518	0.329	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	47.824	122.01	0.77	0.926	0.926	600mmBD / 1200mm x 500mm	0.00333	1.071959735	1.2761425
9.C	3	0.03	0.4	18.8103208	137.684	76.568553	1.7982	20.609	0.47	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	45.922	133.7	0.79	0.880	0.880	600mmBD / 1200mm x 500mm	0.00333	1.071959735	1.2761425
9.D	19.26	0.03	0.3	33.8090129	286.36	197.24341	1.4518	35.261	-	5.2244	1.3727	-2.5008	0.4522	4.5488	94.52	-	-	-	-	-	-	-	-	-	94.52	0.71	3.590	10.251	1800mm x 1650mm U-Drain	1:200	9.763548949	3.2873902
10.A	1.8	0.03	3.0	11.5717142	240.955	192.73474	1.2502	12.822	1.068	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	37.586	175.88	0.84	0.739	8.400	1800mm x 1500mm U-Drain	0.005	8.673063481	3.2122457
10.B	2.7	0.03	0.3	25.1199672	143.429	81.206737	1.7982	26.886	0.168	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	49.726	110.97	0.74	0.618	0.737	600mmBD / 900mm x 400mm	0.005	0.812067369	1.3534789
10.C	0.15	0.03	0.3	19.2561236	166.953	81.206737	2.0805	21.337	0.423	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	46.556	130.92	0.78	0.043	0.086	600mmBD / 900mm x 400mm	1:200	0.812067369	1.3534789
10.D	0.11	0.03	0.3	23.9805847	31.485	76.568553	0.4112	24.392	0.282	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	48.458	119.2	0.78	0.028	0.957	600mmBD / 1200mm x 500mm	0.00333	1.071959735	1.2761425
11.A	5.28	0.03	1.0	15.3263494	114.631	197.24341	0.5812	15.908	0.8	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	41.471	156.42	0.82	1.881	1.881	1800mm x 1650mm U-Drain	1:200	9.763548949	3.2873902
11.B	2.54	0.03	0.3	24.177315	151.345	79.849555	1.8954	26.073	0.168	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	49.726	114.43	0.78	0.614	0.614	600mmBD / 600mm x 600mm	0.005	0.798495549	1.3306259
11.C	5.56	0.03	1.0	17.0653045	74.67	116.86946	0.6389	17.704	0.688	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	42.981	145.86	0.8	1.800	1.800	1200mm x 900mm U-Drain	0.00333	2.10365025	1.9478243
11.D	1.43	0.03	0.3	24.4181402	87.738	90.775754	0.9665	25.385	0.235	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	49.092	116.04	0.75	0.346	0.959	600mmBD / 800mm x 700mm	0.005	1.210343393	1.5129292
11.E(i)	0.63	0.03	0.1	33.6605736	64.614	73.819452	0.8753	34.556	-	5.2244	1.365	-2.4723	0.4446	4.5616	95.74	-	-	-	-	-	-	-	-	-	95.74	0.72	0.121	0.121	600mmBD / 600mm x 400mm	1:200	0.590555617	1.2303242
11.E(ii)	0.22	0.03	0.1	32.9427106	14.43	81.206737	0.1777	33.12	-	5.2244	1.3488	-2.4135	0.4288	4.5884	98.33	-	-	-	-	-	-	-	-	-	98.33	0.723	0.043	0.043	600mmBD / 900mm x 400mm	1:200	0.590555617	1.2303242
11.F	8.47	0.03	3.0	12.3202491	109.657	192.73474	0.569	12.889	1.068	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	37.586	174.96	0.84	3.458	7.741	1800mm x 1500mm U-Drain	0.005	8.673063481	3.2122457
11.G	7.01	0.03	3.0	9.480453336	163.109	139.37346	1.1703	10.651	1.28	5.2244	1.3105	-2.2789	0.3935	4.6494	104.52	52.262	5.2244	1.5776	-3.3024	0.6864	4.1859	65.75	65.75	34.996	197.15	0.857	3.290	4.283	600mmBD / 1700mm x 1100mm	0.005	4.90129992	2.322891
11.H	4.84	0.03	0.3	30.324487	156.125	120.64316	1.2941	31.619	-	5.2244	1.3307	-2.3490	0.4120	4.6172	101.21	-	-	-	-	-	-	-	-	-	101.21	0.73	0.993	2.780	600mmBD / 1200mm x 1100mm	0.005	3.136722186	2.0107194



Comparison between Design Q and Calculated Q
Flowrate (m³/s)
20
18
16
14
12
10
8
6
4
2
0
Design Q
Calculated Q
4.A
4.B
4.C
4.D
4.E
4.F
4.G
4.H
4.I
5.A
5.B
5.C
5.D
6.B
7.A
7.C
8.A
8.B
8.D
9.A
9.B
9.C
9.D
10.A
10.B
10.C
10.D
11.A
11.B
11.C
11.D
11.E(i)
11.E(ii)
11.F
11.G
11.H
Catchment

APPENDIX D –

RAINFALL DATA FROM

BOTA PUMP STATION

Daily totals Year 2000 site 4309092 RUMAH PAM BOTA at PERAK
Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	22.5	0	0	0	0	0	15	63	0	2.5	0	4
2	20.5	0	0	0	21.5	0	0	0	19.5	9.5	0	2.5
3	15	0	0	0	0	0	0	7.5	0	22	0	0
4	50	0	0	36	0	0	0	0	0	0	0	0
5	0	0	0	0	0	32	0	16	0	0	0	13
6	0	7	54	0	0	7	0	0	0	0	0	0
7	7	0	17	0	0	1.5	0	2.5	0	0	57	0
8	0	6	0	13.5	0	0	0	0	0	0	105	0
9	0	0	0	5	0	0	0	28	0	0	0	0
10	0	0	0	21.5	0	9.5	0	74	0	0	70	0
11	0	50	4	0	0	5	0	0	0	0	25	0
12	0	4	0	0	0	0	0	5	25	5	0	0
13	0	26	0	0	0	0	0	0	0	0	0	4.5
14	0	19	0	0	0	0	0	6	0	14.5	32	50
15	0	47	0	0	0	0	0	0	0	25.5	10.5	12
16	50	25	0	0	0	0	0	0	50	9	13.5	3
17	13.5	0	0	0	0	0	0	0	25	17.5	3.5	20.5
18	0	0	68	0	0	64	15	0	59	17	0	45
19	0	13	0	0	0	0	1	0	0	0	7.5	3.5
20	0	0	0	21.5	0	0	0	16	22.5	0	40	19
21	0	34.5	0	0	0	10	0	0	11	0	0	27.5
22	0	10	14	0	0	0	18	0	0	0	0	0
23	38.5	8.5	32.5	3	9.5	0	0	0	17	7	0	0
24	15	6.5	0	0	4	0	8	0	3	17	0	22.5
25	0	0	16	0	0	0	0	0	35	2	0	0
26	0	4	12	20	0	20.5	0	0	9	5	40	0
27	0	0	0	0	48	0	25	0	4	36	0	27.5
28	0	0	0	0	0	0	0	0	8.5	0	0	15
29	0	0	45	5	3.5	0	0	0	57	0	0	0
30	0		25.5	8	0	0	0	0	14	0	0	15
31	0		28		0		4	0		0		0

Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Tot	232	260.5	316	133.5	86.5	149.5	86	218	359.5	189.5	404	284.5	2719.5
Max	50	50	68	36	48	64	25	74	59	36	105	50	105
NO>0.0	9	14	11	9	5	8	7	9	15	14	11	16	128

Daily totals Year 2001 site 4309092 RUMAH PAM BOTA at PERAK
Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	17	0	15	0	0	0	12	29.5	0
2	45.5	20	0	30.5	0	0	0	0	0	0	0	8
3	0	13	25.5	0	0	0	0	0	0	4	0	3.5
4	0	12.5	10	25	0	0	0	0	0	0	3	0
5	0	0	16	7	0	4	0	0	0	52	0	0
6	6.5	0	122	3	40	34.5	0	0	42	0	41.5	0
7	8	10	15.5	0	0	0	0	0	0	0	3.5	0
8	3.5	0	0	6	0	0	0	0	0	0	0	0
9	10	55	0	4	0	0	0	0	0	0	0	0
10	1.5	60	39	0	0	0	0	0	0	0	0	0
11	21.5	0	0	0	9	0	0	0	0	23.5	0	0
12	0	21.5	0	15.5	0	0	0	0	0	0	0	0
13	40.1	65	0	0	0	0	0	0	0	0	23.5	78.5
14	22.5	11	0	43.5	0	0	0	0	40	16.5	0	0
15	0	0	0	3	0	12.5	0	0	15.5	27	0	0
16	0	25	0	4.5	0	0	0	0	6.5	0	0	5
17	0	0	0	0	0	0	0	0	4.5	4	7	18.5
18	0	0	0	0	0	0	0	0	5	0	3	0
19	0	0	0	0	0	0	0	16.5	0	0	0	6
20	0	0	0	23.5	0	0	17	16	4	3.5	0	0
21	11.5	0	0	11.5	0	0	2	0	22	0	0	0
22	0	0	9.5	6.5	0	0	9.5	0	0	0	8	15
23	10	0	0	3	0	0	3	0	0	0	8.5	0
24	0	0	0	36	0	0	0	0	0	18.5	75.5	0
25	36.5	30.5	0	7	0	0	0	16	0	35	50	0
26	0	0	0	20	0	0	0	0	6	0	0	0
27	0	0	0	3	0	0	0	0	0	4	0	12
28	5	0	0	33.5	0	0	91.5	0	0	80	0	0
29	14.5		0	0	0	0	8	4	13	4.5	27	0
30	0		0	7	0	0	39	0	14	0	0	0
31	0		0		0		10	0		0		0

Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Tot	236.6	323.5	237.5	310	49	66	180	52.5	172.5	284.5	280	146.5	2338.6
Max	45.5	65	122	43.5	40	34.5	91.5	16.5	42	80	75.5	78.5	122
NO>0.0	14	11	7	21	2	4	8	4	11	13	12	8	115

Daily totals Year 2002 site 4309092 RUMAH PAM BOTA at PERAK
Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	35	3	2.5	0	0
2	0	0	6.5	7.5	0	0	0	0	5	17.5	14.5	6.5
3	0	0	0	0	26	0	0	0	11.5	0	0	0
4	10	0	0	0	0	0	0	0	0	0	49	0
5	13	0	0	0	69	0	0	0	0	0	2	0
6	0	0	4	32.5	0	0	0	0	7	53	0	0
7	0	0	0	0	0	0	0	0	26	0	0	4
8	0	0	0	3	3	0	0	0	5	3.5	19.5	0
9	0	0	0	10.5	0	10.5	49.5	0	10.5	0	0	0
10	0	0	0	0	0	10	0	0	0	35	5	70.5
11	0	0	0	0	0	2	0	0	0	30.5	10	34.5
12	0	3	0	0	0	29	0	0	0	0	0	4.5
13	0	0	0	44	0	0	0	0	0	0	67.5	0
14	6	23	31.5	70.5	0	0	0	0	13	0	56	0
15	0	0	0	0	0	10	0	0	0	0	7.5	16.5
16	31	5	0	9	0	0	0	0	7.5	0	3.5	62.5
17	0	0	0	0	2.5	0	0	27	0	4.5	12.5	0
18	0	3	18.5	0	0	0	0	0	0	0	4	0
19	11	0	0	0	0	0	0	0	0	0	11.5	56.5
20	0	26	0	0	0	0	0	0	0	16.5	0	0
21	50	0	3.5	0	0	0	0	0	42	0	0	0
22	0	16.5	3	0	0	0	0	25	0	0	5	0
23	0	0	10.5	0	0	0	0	0	0	0	25.5	0
24	8	0	0	0	0	0	0	8	0	6.5	0	0
25	0	0	8	11	0	0	0	0	48.5	0	4.5	61
26	0	36.5	0	35	21.5	5	0	0	8	0	0	13.5
27	5	42.5	9.5	36.5	0	0	0	0	33	5	0	0
28	0	0	36.5	58	0	0	31.5	0	4	0	0	0
29	0		0	57	0	0	0	16	0	0	0	0
30	0		0	12	0	0	8.7	0	0	13	5	8
31	0		0		0		0	6		27		0

Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Tot	134	155.5	131.5	386.5	122	66.5	89.7	117	224	214.5	302.5	338	2281.7
Max	50	42.5	36.5	70.5	69	29	49.5	35	48.5	53	67.5	70.5	70.5
NO>0.0	8	8	10	13	5	6	3	6	14	12	17	11	113

Daily totals Year 2003 site 4309092 RUMAH PAM BOTA at PERAK
Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	4.5	0	0	3	3	0	0	0	0	50.5	0	11
2	29.5	16	0	0	0	0	5.5	0	0	33.5	17	3.5
3	0	0	0	0	0	0	0	0	0	6	12	0
4	0	0	0	4	0	0	0	0	0	0	5.5	12.5
5	0	0	18.5	0	0	50.5	0	0	0	0	0	4
6	9	0	0	11	0	28	7.5	0	0	9.5	8	0
7	0	0	0	0	0	0	0	0	19.5	12	10.5	0
8	0	24.5	0	4.5	14	0	0	0	0	0	27	2.5
9	38.5	8	0	64.5	0	0	0	0	0	0	6.5	10.5
10	0	0	7.5	18	76.5	0	45.5	33	0	6	6	0
11	0	0	26	0	2	0	0	18	0	23	3.5	0
12	0	36	0	22	8	0	0	5	4.5	0	0	0
13	0	0	0	13.5	17	0	0	0	0	0	0	0
14	21	23	0	0	0	0	11.5	0	0	0	69.5	0
15	0	0	0	17	0	0	0	19	0	0	0	21.5
16	0	0	11	17	0	9.5	0	0	36	0	0	0
17	11	19	0	0	0	0	30.5	0	0	0	41	0
18	4.5	0	0	0	0	0	8	0	5.5	23.5	4.5	0
19	0	36	17.5	0	0	0	0	0	0	83.5	0	0
20	0	0	0	66.5	0	0	3.5	0	0	38.5	22	4.5
21	10	0	0	0	0	0	0	0	0	0	0	0
22	0	18	5	0	0	0	25.5	0	0	12	10	0
23	0	0	24	3	0	0	0	6.5	4	0	0	0
24	0	0	5	0	24.5	0	0	7	0	0	55	0
25	0	0	0	0	4	0	28.5	0	2.5	0	17	0
26	0	0	8	0	8	30	5.5	3.5	0	0	9.5	0
27	0	0	0	24.5	0	10.5	0	0	0	38.5	3.5	0
28	0	0	6	0	0	4.5	0	10.5	0	13	0	0
29	0		0	56.5	0	0	0	0	0	0	4	0
30	44.5		0	13.5	0	56.5	0	0	0	6	0	8
31	25.5		0		0		0	0		77		9

Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Tot	198	180.5	128.5	338.5	157	189.5	171.5	102.5	72	432.5	332	87	2389.5
Max	44.5	36	26	66.5	76.5	56.5	45.5	33	36	83.5	69.5	21.5	83.5
NO>0.0	10	8	10	15	9	7	10	8	6	15	19	10	127

Daily totals Year 2004 site 4309092 RUMAH PAM BOTA at PERAK
Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	15	12.5	0	46	0	0	0	0	16	0	?	0
2	10	0	0	17.5	0	0	0	0	4.5	14	?	3.5
3	0	4.5	0	0	0	0	17.5	0	0	0	?	0
4	0	0	0	0	0	0	8.5	0	0	0	?	24
5	0	0	0	0	74	0	42	0	0	0	?	3
6	0	0	0	0	0	0	0	0	0	29	?	0
7	0	0	0	0	0	0	5	0	0	0	?	0
8	15	25.5	5	0	0	0	56.5	0	0	0	?	4.5
9	0	10	0	13	0	0	7	0	0	0	?	23
10	4	1	59	52.5	0	0	0	54	0	19	?	1
11	2.5	0	12	0	0	0	0	0	64	0	?	2.5
12	0	0	0	7	0	0	0	0	12	10	?	0
13	0	0	25	0	0	0	0	0	0	0	?	0
14	0	0	7	0	0	0	13.5	14.5	12	0	?	0
15	0	0	3.5	0	0	0	10.5	0	0	0	?	0
16	0	0	0	36	0	0	0	0	0	0	?	0
17	0	0	0	59.5	0	0	0	0	0	0	?	0
18	0	0	0	0	0	0	20.5	0	31.5	0	?	0
19	0	0	5.5	0	0	0	19	0	0	0	?	0
20	4	13.5	0	0	0	0	0	0	27	89	?	0
21	0	0	0	4	0	0	0	0	11	44.5	?	0
22	0	0	0	11	0	0	0	0	28	0	?	0
23	0	2	23.5	0	0	0	0	0	0	0	?	0
24	0	6.5	55.5	1	0	8	0	0	0	30.5	?	4
25	3.5	4	33.5	0	0	0	0	0	20.5	24.5	?	34
26	0	4.5	0	16	25	0	37	0	24	0	?	0
27	23	2.5	0	29	12	4.5	0	6	7	35	?	31
28	5	0	5.5	0	39	0	0	0	0	29	?	2.5
29	14.5	0	0	0	0	0	0	0	0	4	?	9
30	0		0	0	0	35	0	0	0	0	?	0
31	0		17.5		0		0	0		?		0

Min	0	0	0	0	0	0	0	0	0	0	?	0	0
Tot	96.5	86.5	252.5	292.5	150	47.5	237	74.5	257.5	328.5	?	142	1965
Max	23	25.5	59	59.5	74	35	56.5	54	64	89	?	34	89
NO>0.0	10	11	12	12	4	3	11	3	12	11	0	12	101

Daily totals Year 2005 site 4309092 RUMAH PAM BOTA at PERAK
Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	16.5	0	0	0	28	0	0	0	0	0	0	0	
2	0	0	0	17.5	27	0	0	0	0	0	8	0	
3	0	17	0	0	5	17.5	0	0	0	0	0	0	
4	0	0	46.5	0	0	0	0	0	0	0	0	12	
5	0	0	35	0	0	0	0	0	0	0	0	0	
6	0	0	0	0	0	0	0	0	2	0	0	4.5	
7	0	0	0	9.5	0	0	0	0	4	0	8.5	0	
8	27.5	0	0	2.5	0	0	0	0	0	0	3.5	0	
9	0	0	0	0	0	0	0	0	0	23	5.5	0	
10	0	0	0	0	0	0	0	0	0	0	0	22.5	
11	5	0	0	0	0	0	24.5	0	0	0	0	0	
12	0	0	0	0	33.5	0	0	0	0	65	0	14	
13	0	0	13	30	9	0	0	0	0	0	0	0	
14	0	0	0	9.5	4.5	0	28	0	0	0	0	0	
15	22	5.5	0	0	4	0	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	67.5	0	0	58	
17	0	0	0	0	0	19	12	5	3.5	4	0	114	
18	0	0	0	0	0	0	0	0	0	2	18.5	0	
19	0	0	4.5	0	0	5.5	0	4	0	0	0	0	
20	0	0	8	0	0	0	0	0	18	0	8	0	
21	0	0	10	0	0	5	0	0	0	0	26.5	0	
22	0	0	0	0	0	0	0	0	0	0	2	0	
23	0	0	0	0	0	0	0	2	0	6	20.5	20	
24	0	0	0	0	26	0	0	0	0	13.5	0	0	
25	0	0	8	0	0	0	0	0	0	6.5	0	0	
26	0	29.5	32	0	0	4	0	0	0	0	65.5	0	
27	0	0	0	0	0	0	0	0	118.5	5	0	0	
28	0	0	3	20	14	0	0	0	22	0	0	0	
29	0		9	0	0	0	0	0	0	47.5	16.5	0	
30	0		4	12	0	0	0	0	5	0	9.5	90	
31	21		18		0		0	0		0		17	
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Tot	92	52	191	101	151	51	64.5	11	240.5	172.5	192.5	352	1671
Max	27.5	29.5	46.5	30	33.5	19	28	5	118.5	65	65.5	114	118.5
NO>0.0	5	3	12	7	9	5	3	3	8	9	12	9	85

Daily totals Year 2006 site 4309092 RUMAH PAM BOTA at PERAK
Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	4.5	0	0	0	10	0
2	9.5	0	97.5	0	0	8	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	15	0	0	0	0	0	0	0	10	0	0	0
5	0	0	0	0	0	4	0	0	20	0	0	22.5
6	46.5	0	0	0	0	0	0	0	65.5	0	0	31.5
7	0	0	6.5	0	0	0	0	0	0	0	190	0
8	0	0	0	0	8	0	0	0	0	0	8.5	0
9	0	0	0	0	0	7.5	0	0	13	0	12	64.5
10	12.5	56.5	0	0	0	0	21.5	0	0	0	33.5	0
11	0	34	0	0	0	0	0	0	12.5	0	0	0
12	0	0	0	0	48	14.5	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	8	0	0	57
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	82	28	0	0	0	0	0	65	70.5
16	0	0	0	0	0	0	0	0	7.5	0	0	17
17	17.5	46	32.5	0	0	0	0	0	0	150	24.5	0
18	0	0	0	59	0	0	0	5.5	0	75	29.5	0
19	0	0	0	30	0	0	0	0	0	0	0	6
20	0	0	0	0	20	0	0	0	0	150	10.5	0
21	0	4.5	29.5	0	0	33.5	0	0	25	4.5	24	0
22	0	9.5	0	15	0	5	0	10.5	0	0	0	0
23	0	0	0	0	15	18	0	0	0	79.5	48	0
24	0	0	0	0	0	15	0	0	0	10	0	0
25	0	0	0	115	0	0	0	20.5	0	12.5	70	0
26	0	0	0	0	18	0	47	0	0	0	26.5	0
27	0	0	0	0	13	15	0	0	0	5.5	8	0
28	0	0	0	16	0	0	8	5.5	0	10.5	11	0
29	0		0	0	14	0	4	0	0	8.5	4	0
30	0		0	0	0	0	0	0	0	45.5	12	0
31	0		0		12.5		0	0		0		0

Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Tot	101	150.5	166	317	176.5	120.5	85	42	161.5	551.5	587	269	2727.5
Max	46.5	56.5	97.5	115	48	33.5	47	20.5	65.5	150	190	70.5	190
NO>0.0	5	5	4	6	9	9	5	4	8	11	17	7	90

Daily totals Year 2007 site 4309092 RUMAH PAM BOTA at PERAK

Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	39.5	0	0	0
2	0	0	0	0	0	42	0	0	3.5	0	0	0
3	0	0	0	0	0	27	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	7	0	0
6	18	0	0	0	0	0	19.5	0	15	15	11	0
7	0	0	0	0	0	0	0	0	0	8	0	0
8	0	0	0	0	2	0	0	0	2.5	0	0	10.5
9	20	0	0	0	0	0	0	0	0	0	7	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	8	0	32	0	22	0	0	0	22	0	20
12	20	54.5	0	23	0	0	0	0	0	0	0	0
13	14.5	0	0	0	17	113	0	0	0	0	44.5	0
14	0	22	0	0	4.5	3	12	0	0	40	0	0
15	0	20	0	9	0	0	0	10.5	35	50	0	0
16	0	10.5	0	0	0	0	0	0	0	0	0	0
17	0	25	10	0	0	21	0	1.5	0	26	0	112
18	34	15	8	0	0	0	0	0	0	0	0	1
19	0	0	0	0	0	0	0	8	0	50	17	30
20	83.5	28.5	25	0	0	0	28	35.5	0	0	0	20
21	0	8.5	0	20	0	0	47	0	0	79	5	0
22	0	0	6	0	0	0	0	0	0	0	0	0
23	0	10.5	0	31	27.5	0	30	0	0	15	6.5	0
24	0	8	0	0	7.5	0	5.5	0	0	6	0	0
25	9	0	0	21	52	0	103	0	0	0	0	0
26	0	0	0	7.5	10	0	12	0	0	61	0	0
27	0	0	0	25.5	0	0	31	0	0	0	0	0
28	0	22.5	14	40	0	0	0	0	0	0	0	0
29	0		40	8.5	0	0	0	10	0	0	0	0
30	0		11	14	0	0	0	0	0	24	0	0
31	0		0		0		0	0		0		0

Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Tot	199	233	114	231.5	120.5	228	288	65.5	95.5	403	91	193.5	2262.5
Max	83.5	54.5	40	40	52	113	103	35.5	39.5	79	44.5	112	113
NO>0.0	7	12	7	11	7	6	9	5	5	13	6	6	94

Daily totals Year 2008 site 4309092 RUMAH PAM BOTA at PERAK

Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	9.5	0	0	0	0	0	0	0	0	0	7	0
2	0	0	27	21	0	35	50	0	0	0	0	0
3	0	0	0	0	0	1.5	0	0	50	4	0	0
4	7	0	35	16	0	0	0	0	0	0	0	15.5
5	0	0	0	0	0	18	0	0	0	0	0	0
6	70.5	0	26	16	0	0	0	0	0	20	0	0
7	81	0	0	1.5	0	0	0	0	25.5	5.5	0	0
8	0	0	0	0	0	0	0	0	0	0	0	15
9	37.5	0	39	18	0	8	0	0	52	90	38	10
10	0	0	36	0	0	0	0	0	3	35.5	0	12.5
11	0	0	110	100	0	0	0	20.5	0	0	60	14.5
12	0	0	0	20	0	0	0	0	0	25	23	10
13	0	0	25	43	0	0	100	0	5	4	0	50.5
14	8.5	0	0	0	0	0	17	0	0	30	0	0
15	0	0	0	0	0	0	0	0	0	8	53	0
16	10.5	0	0	0	0	0	0	0	0	22	0	0
17	0	0	0.5	11	0	0	0	153	0	9	0	0
18	0	0	4	0	0	0	0	0	0	35	41	0
19	0	0	6	0	0	0	37	6.5	0	42	0	0
20	0	0	0	7.5	0	0	41	18	0	47.5	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	75	0	16	0	9.5	43	8	4.5	0	0
23	0	55	17.5	0	0	0	7	13	0	3	28	50
24	0	0	40.5	0	0	0	0	14	0	0	25	0
25	0	0	0	0	12	0	0	32.5	4.5	0	59.5	0
26	79	35	0	0	0	0	0	0	0	0	0	0
27	0	20	0	14	0	0	0	0	0	0	4	0
28	0	0	0	0	0	52	0	5	0	0	0	43
29	0	0	0	0	25	0	0	0	0	0	0	0
30	0		45.5	0	0	0	0	12	0	0	0	0
31	0		0		5		0	25		0		0

Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Tot	303.5	110	487	268	58	114.5	261.5	342.5	148	385	338.5	221	3037.5
Max	81	55	110	100	25	52	100	153	52	90	60	50.5	153
NO>0.0	8	3	14	11	4	5	7	11	7	16	10	9	105

Daily totals Year 2009 site 4309092 RUMAH PAM BOTA at PERAK
Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	20.5	30.5	0
2	0	0	19	13	15	0	0	0	0	8.5	0	0
3	0	0	0	0	0	0	0	5	0	0	37.5	50
4	12	0	0	15	5	0	0	0	22.5	25	0	0
5	0	0	30	0	0	0	0	0	0	6	0	0
6	0	0	15.5	0	0	0	5	0	0	0	30	0
7	13	0	0	0	0	0	0	0	0	0	21	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	37.5	0	0	0	0	0	0	58	50
10	0	0	0	12	0	0	0	0	0	5.5	0	0
11	0	0	9	15	0	0	0	0	0	0	0	0
12	0	0	15.5	0	8	0	0	0	25	4	50	0
13	39	0	31.5	19	0	0	0	0	0	2	0	0
14	0	0	0	0	0	0	0	5	0	0	86	40
15	0	0	4.5	40	0	0	0	0	0	20	0	0
16	21	7	0	0	48	0	0	0	35	16	4	0
17	0	0	0	0	0	0	0	15	48.5	0	5	50
18	0	0	0	0	0	0	0	6	15	0	8	0
19	0	20	22	5	0	0	0	7	0	0	2	0
20	0	0	0	0	0	0	48	11	0	0	34.5	0
21	15	15	0	0	6	0	0	9	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	12.5	0	0	0	0	0	4	0	0	0	10
24	13	7	50	0	0	64	0	0	0	53	0	0
25	0	5	0	0	0	0	0	13.5	0	0	0	0
26	0	0	0	0	0	0	0	31	0	0	0	50.5
27	0	21	13	0	0	0	0	0	0	0	0	0
28	0	27.5	0	0	4	0	0	8	72	0	30	0
29	0		0	0	0	0	0	0	17	0	0	48
30	0		0	0	0	0	0	0	0	0	0	0
31	17		0		0		0	0		0		?

Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Tot	130	115	210	156.5	86	64	53	114.5	235	160.5	396.5	298.5	2019.5
Max	39	27.5	50	40	48	64	48	31	72	53	86	50.5	86
NO>0.0	7	8	10	8	6	1	2	11	7	10	13	7	90

End of process

APPENDIX E –

DRAIN SIZE AND

CHARACTERISTICS

APPENDIX E - Drain Size and Characteristics

Size	Width (m)	Depth (m)	n	Area (drain)	Area (wall)	Area (total)	Perimeter (drain)	Perimeter (Wall)	Perimeter (total)	R	S	V (m/s)	V (m/min)	Q (m3/s)
U-Drain														
600mm x 400mm U-Drain	0.6	0.4	0.015	0	0.24	0.24	0	1.4	1.4	0.1714	0.0033	1.1878	71.2669	0.2851
1200mm x 900mm U-Drain	1.2	0.9	0.015	0	1.08	1.08	0	3.0	3.0	0.36	0.0033	1.9478	116.869	2.1037
1200mm x 1050mm U-Drain	1.2	1.05	0.015	0	1.26	1.26	0	3.3	3.3	0.3818	0.0016	1.3891	83.3465	1.7503
1500mm x 1500mm U-Drain	1.5	1.5	0.015	0	2.25	2.25	0	4.5	4.5	0.5	0.005	2.9697	178.18	6.6817
1800mm x 1500mm U-Drain	1.8	1.5	0.015	0	2.7	2.7	0	4.8	4.8	0.5625	0.005	3.2122	192.735	8.6731
1800mm x 1650mm U-Drain	1.8	1.65	0.015	0	2.97	2.97	0	5.1	5.1	0.5824	0.005	3.2874	197.243	9.7635
1800mm x 1650mm U-Drain	1.8	1.65	0.015	0	2.97	2.97	0	5.1	5.1	0.5824	0.0067	3.796	227.757	11.274
1800mm x 1650mm U-Drain	1.8	1.65	0.015	0	2.97	2.97	0	5.1	5.1	0.5824	0.008	4.1583	249.495	12.35
Block Drain														
400mmBD	0.4	0.4	0.015	0.106666667	0	0.106666667	1.466666667	0	1.466666667	0.0727	0.005	0.8213	49.2807	0.0876
500mmBD	0.5	0.5	0.015	0.166666667	0	0.166666667	1.833333333	0	1.833333333	0.0909	0.005	0.9531	57.1851	0.1588
600mmBD	0.6	0.6	0.015	0.24	0	0.24	2.2	0	2.2	0.1091	0.005	1.0763	64.5759	0.2583
600mmBD / 600mm x 400mm	0.6	0.4	0.015	0.24	0.24	0.48	2.2	1.4	3.6	0.1333	0.005	1.2303	73.8195	0.5906
600mmBD / 600mm x 600mm	0.6	0.6	0.015	0.24	0.36	0.6	2.2	1.8	4	0.15	0.005	1.3308	79.8496	0.7985
600mmBD / 800mm x 300mm	0.8	0.3	0.015	0.24	0.24	0.48	2.2	1.4	3.6	0.1333	0.005	1.2303	73.8195	0.5906
600mmBD / 800mm x 700mm	0.8	0.7	0.015	0.24	0.56	0.8	2.2	2.2	4.4	0.1818	0.005	1.5129	90.7758	1.2103
600mmBD / 900mm x 400mm	0.9	0.4	0.015	0.24	0.36	0.6	2.2	1.7	3.9	0.1538	0.005	1.3535	81.2087	0.8121
600mmBD / 1100mm x 1000mm	1.1	1.0	0.015	0.24	1.1	1.34	2.2	3.1	5.3	0.2528	0.005	1.8849	113.092	2.5257
600mmBD / 1200mm x 500mm	1.2	0.5	0.015	0.24	0.6	0.84	2.2	2.2	4.4	0.1909	0.0033	1.2761	76.5686	1.0720
600mmBD / 1200mm x 1100mm	1.2	1.1	0.015	0.24	1.32	1.56	2.2	3.4	5.6	0.2786	0.005	2.0107	120.643	3.1367
600mmBD / 1600mm x 400mm	1.6	0.4	0.015	0.24	0.64	0.88	2.2	2.4	4.6	0.1913	0.005	1.5651	93.9063	1.3773
600mmBD / 1700mm x 1100mm	1.7	1.1	0.015	0.24	1.87	2.11	2.2	3.9	6.1	0.3459	0.005	2.3229	139.373	4.9013